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FORM PTO-1390 (REV 11-2000) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY'S DOCKET NUMBER: 2541-000008

U.S. APPLICATION NO. (If known, see 37 CFR 1.5: 09/889460

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/FR00/00120	20 January 2000 (20.01.00)	21 January 1999 (21.01.99) *

TITLE OF INVENTION ELECTROMAGNETIC RADIATION (E.M.R.) HEAT, SENSOR ARRAY AND METHOD FOR MAKING SAME

APPLICANT(S) FOR DO/EO/US YON, Jean-Jacques; VILAIN, Michel and OUVRIER-BUFFET, Jean-Louis

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND or SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   - a. ☐ is attached hereto (required only if not communicated by the International Bureau).
   - b. ☒ has been communicated by the International Bureau.
   - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   - a. ☒ is attached hereto.
   - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☐ Amendments to the claims of the International Aplication under PCT Article 19 (35 U.S.C. 371(c)(3))
   - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   - b. ☐ have been communicated by the International Bureau.
   - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   - d. ☐ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English lanugage translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. ☒ A FIRST preliminary amendment.
14. ☐ A SECOND or SUBSEQUENT preliminary amendment.
15. ☐ A substitute specification.
16. ☐ A change of power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
18. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. ☒ Other items or information:

* Priority claimed from French Patent Application No. 99-00632, filed January 21, 1999
Application under 35 U.S.C. 371, Application Data Sheet, 4 sheets of formal drawings showing Figs. 1 - 12, and return postcard.

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U.S. APPLICATION NO. (if known, see 37 CFR 1.5) 09/889460	INTERNATIONAL APPLICATION NO. PCT/FR00/00120	ATTORNEY'S DOCKET NUMBER 2541-000008

21. [X] The following fees are submitted:

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)):

Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a (2)) paid to USPTO and International Search Report not prepared by the EPO or JPO **$1000.00**

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO **$860.00**

International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO **$710.00**

International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$690.00**

International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) **$100.00**

				CALCULATIONS	PTO USE ONLY
ENTER APPROPRIATE BASIC FEE AMOUNT =				$ 860.00	
Surcharge of **$130.00** for furnishing the oath or declaration later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(e)).				$ 0.00	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	$	
Total claims	16 -20 =	0	**x $18.00**	$ 0.00	
Independent claims	1 -3 =	0	**x $80.00**	$ 0.00	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			**+ $270.00**	$ 0.00	
TOTAL OF ABOVE CALCULATIONS =				$ 860.00	
[ ] Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2. +				$ 0.00	
SUBTOTAL =				$ 860.00	
Processing fee of **$130.00** for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				$ 0.00	
TOTAL NATIONAL FEE =				$ 860.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +				$ 0.00	
TOTAL FEES ENCLOSED =				$ 860.00	
				Amount to be refunded:	$
				charged:	$

a. [X] A check in the amount of $ 860.00 to cover the above fees is enclosed.

b. [ ] Please charge my Deposit Account No. ________ in the amount of $ ________ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. [X] The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 08-0750. A duplicate copy of this sheet is enclosed.

d. [ ] Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137 (a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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34,811
REGISTRATION NUMBER

Date: July 16, 2001

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PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application No.:	Not yet assigned
Filing Date:	Herewith
Applicant:	YON, et al.
Title:	ELECTROMAGNETIC RADIATION (E.M.R.) HEAT, SENSOR ARRAY AND METHOD FOR MAKING SAME
Attorney Docket:	2541-00008

Box Patent Applications
Hon. Commissioner of Patents and Trademarks
Washington, D.C. 20231

PRELIMINARY AMENDMENT

Sir:

Applicants herewith submit this Preliminary Amendment to the application filed herewith, for consideration prior to the calculation of the filing fee, as follows:

IN THE CLAIMS

Please cancel claims 1 – 16 and replace with new claims 17 – 32.

17. (New) Electromagnetic radiation heat detecting device comprising at least two microbridge detectors with mechanical support devices with a signal processing circuit provided by the detectors in which microbridge suspended layers of two neighboring detectors are linked together by additional mechanical connections separate from the mechanical support devices.

18. (New) Device according to claim 17, in which each of the mechanical connections is an extension of at least one of the suspended microbridge layers.

19. (New) Device according to claim 17, in which each of the mechanical

connections comprise a material with low thermal conductivity.

20. (New) Device according to claim 17, in which each of the mechanical connections are in line with two mechanical support devices, each belonging to one of two neighboring detectors.

21. (New) Device according to claim 17 in which the said device forms a repetitive detector configuration according to a linear or matrix architecture.

22. (New) A process for manufacturing a device according to claim 17 which, starting from a processing circuit with metallic contact blocks visible on the surface, comprises the following steps:

(a) forming a reflector on a surface of the processing circuit through deposit of a metallic coat with definition through photolithography;

(b) forming an optical cavity through deposit of a sacrificial layer which is later removed;

whereby at least two layers constituting the microbridge are laid, one of said layers being a layer of heat-sensitive material, and another of said layers being a conducting coat constituting the detector electrodes;

(c) forming the mechanical support and the electrical interconnection devices which are made against the contact blocks, by etching of the sacrificial layer, the layer of heat sensitive material and the conducting coat, and by depositing and etching at least one metallic coat which provides the electrical and mechanical continuity between the contact blocks and the microbridge electrodes;

(d) forming the detector electrodes defined by etching the conducting coat; and

(e) forming the layer of heat-sensitive material, the conducting coat and optional

layers by etching simultaneously using a mask to shield a zone located between the detectors.

23. (New) The process according to claim 22, in which the layer of heat-sensitive material is a layer of amorphous silicon.

24. (New) The process according to claim 22, in which the conducting coat constituting the detector electrodes is a layer of titanium nitride.

25. (New) The process according to claim 22 in which a layer of aluminium is deposited to provide the electrical continuity between the electric blocks and the microbridge electrodes.

26. (New) The process according to claim 22, in which the metallic coat constituting the detector electrodes, is removed in the zones occupied by the mechanical connections

27. (New) The process according to claim 22 in which, after the definition stage of the detector electrodes by etching of the conducting coat, a final layer is deposited.

28. (New) The process according to claim 27 in which the final layer is a layer of material selected from the group consisting of silicon dioxide, silicon nitride, amorphous silicon and mixtures thereof.

29. (New) The process according to claim 22 in which the mechanical connections are fined down due to partial etching of these connections.

30. (New) The process according to claim 29 in which the conducting coat and the final layer are removed at the connections.

31. (New) The process according to claim 22 in which a connection element of a material with a low thermal conductivity is added on the microbridges entirely isolated

from one another.

32. (New) Process according to claim 31 in which the material with low thermal conductivity is silicon nitride or polymer material.

REMARKS

After entry of this amendment, claims 17 – 32 are pending in the application. Claims 1 – 16 have been cancelled without prejudice. Claims 17 – 32 have been added in this amendment.

It is submitted that this Amendment has antecedent basis in the application as originally filed, including the specification, claims and drawings, and that this amendment does not add any new subject matter to the application. Consideration of the application as amended is requested. It is submitted that this Amendment places the application in suitable condition for allowance; notice of which is requested.

If the Examiner feels that prosecution of the present application can be expedited by way of an Examiner's amendment, the Examiner is invited to contact the Applicants' attorney at the telephone number listed below.

Respectfully submitted,

Dated: 16 July 2001

By: L. Deschere

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09/ 889460

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ENGLISH LANGUAGE TRANSLATION

OF THE

INTERNATIONAL APPLICATION AS FILED,
INCLUDING DRAWINGS

09/889460
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ELECTROMAGNETIC RADIATION

ABSORBER

THERMOMETER

HEAT INSULATION

PROCESSING CIRCUIT

09889460 . 121701

09/889460
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4/PRTS

E.M.R HEAT DETECTING DEVICE AND ITS MANUFACTURING PROCESS

DESCRIPTION

Technical Field

The present invention concerns an E.M.R. heat detecting device and a manufacturing process for this device.

Status of previous techniques

An E.M.R. detector based on the principle of a heat detecting device such as is represented schematically on Figure 1, is generally made up of different subsystems which carry out the four essential functions necessary for the detection of the radiation, i.e.:

- an absorption function

The absorption function allows converting the energy of the E.M. incident wave, which is characteristic of the temperature and the emissivity of the environment under examination in a heating phase of the detection structure. The parameters which characterize this function are:

- On the one hand the relative absorption (Ar) which defines the ratio of the incident radiation luminance to the luminance actually absorbed by the absorbing structure. A quarter-wave resonant optical cavity facilitates obtaining a relative absorption near to the ideal value of 100%.

- On the other hand the fill factor (Fr) which is the ratio between the useful surface actually involved in heating of the detector with the total surface of the latter. In this way one obtains fill factors in the order of 50%.

Optimization of the absorption function consists therefore essentially in maximizing these Fr and Ar parameters.

- a thermometer function

The thermometer is an element where one of the physical characteristics is sensitive to temperature. This can be the electrical resistivity of the material in the case of resistive bolometers, the conductivity of semiconductor devices, residual polarization in the case of a pyroelectric detector, the dielectric constant in the case of a ferroelectric detector, etc. The essential quality factor which characterizes the thermometer function is the relative variation of the physical value observed with the temperature. For a resistive bolometer of R resistance this quality factor is expressed by dR/R.dT, i.e. TCR. Optimization of the thermometer consists in maximizing this parameter.

- a heat insulation function

The thermometer is heat insulated from its environment, for example by placing the thermometer on a suspended diaphragm above a substrate, according to an architecture referred to as "microbridge" which is heat insulated on the one hand by integrating the detector in an environment under reduced gas pressure, and on the other hand by interlacing a specific heat insulation device between the microbridge supporting

the thermometer and the down-circuit signal processing circuit. The characteristic thermal parameters are, on the one hand the thermal impedance Rth which should be maximized so as to improve the sensitivity of the detector, and on the other hand the heat capacity Cth which translates the thermal inertia of the thermometer so as to reduce detector response time to an incident flux variation. Response time which is proportional to the result of Rth x Cth, is typically between several milliseconds and several dozen milliseconds. So as to make a detector both sensitive and at the same time rapid, one should attempt to maximize the effectiveness of the heat insulation and reduce the volume of the thermometer to the minimum. This optimization implies making structures in thin layers.

- the signal processing function:

The signal processing function consists in translating the electric signal issued by the thermometer into a video signal which is usable by camera. This function is realized:

- either by hybridization of the detection circuit on the processing circuit; this initial solution which necessitates treating each component individually, is incompatible with a process where the technological operations of manufacturing are realized simultaneously on a large number of components assembled flat on a substrate. This initial solution therefore poses the problem of high manufacturing cost.

- or by mounting the detector on a microbridge suspended above a pre-existing processing circuit. The component made is then called

"monolithic". This second solution which enables one to circumvent the problem of manufacturing cost, imposes severe restrictions on the technological processes which make the detection structure - particularly the heat budget must be limited so as to avoid downgrading the electrical performance of the processing circuit.

Besides these different functions, moreover one must:

- on the one hand maintain the same mechanical balance between the detector and the processing circuit,
- and on the other hand provide the transmission of the electric signal originating from the thermometer to the processing circuit.

The figures 2 and 3 represent schematically the layout of the different functions necessary for detection. Figure 2 refers to an architecture where the detector is mounted above the processing circuit, whereas figure 3 represents a configuration where these two elements are side by side.

On these two figures, the following are shown:

- a zone 10 which constitutes the thermometer and corresponds to the active zone of the detector which actually collects the incident photons
- zones 11 which constitute the mechanical support and electrical interconnection devices between the detector and the processing circuit
- zones 12 which constitute the detector heat insulation devices
- and a zone 13 which represents the signal processing circuit.

On figure 2, the zone 13 is not represented, as this is located under the detector.

The devices 11, 12 and 13 are not involved in detection - to maximize the fill factor one should therefore limit the surface necessary for their realization, by:

- limiting their number to the bare minimum, for example, to two;

- limiting their size, by reducing the length of the heat insulation devices, and therefore their cross-section and thickness so as to retain sufficient heat insulation.

- choosing the architecture where the detector is mounted on the processing circuit according to a monolithic architecture.

The European EP-0 354 369 patent request describes in this manner an infrared monolithic uncooled detector network of bolometers made on a silicon substrate. The bolometers comprise a silicon dioxide cell of TiN (titanium nitride), a-Si:H (hydrogenated amorphous silicon), TiN and silicon dioxide. The titanium nitride forms the infrared absorber and the resistor contacts, and the amorphous silicon, the resistance with a high temperature resistivity factor. The resistor is suspended above the silicon substrate by metal interconnections and the accompanying processing circuit takes shape in the silicon substrate under the resistor.

To minimize the mechanical deformations of fine structures set up, an initial solution consists in compensating the stresses that develop in a thin layer

by the arrangement of an additional layer in contact with this layer.

The second solution consists in reducing the amplitude of the intrinsic stress of materials used by calling upon heat treatment at high temperatures in order to relieve the stresses. But this solution leads to thermally restricting the electronic processing circuit disposed in layers under the detector and to downgrading functionality of the said circuit.

For the time being we shall consider several examples for realization according to previous technology.

Figure 4 represents a perspective view of a unit detector characterized by heat insulation devices 12 of intermediate length.

Structures made, illustrated in figures 5, 6 and 7, show more often than not an outline sketch of three neighbouring detectors 16, 17 and 18 as part of a generally more complex structure, multi-element linear array strip or forming two sizes of detectors.

In the realization illustrated in figure 5, heat insulation is maximized thanks to very long heat insulation devices 12, accompanying the mechanical support and electrical interconnection devices 11. This realization presents the following disadvantages:

- a reduced active zone 10 due to the bulk of insulation devices, hence a low fill factor;

- a tendency of the part 12 to sag due to its length, which necessitates a thicker diaphragm to ensure the mechanical stiffness.

In the realization illustrated in figure 6, the fill factor is maximized by limiting the surface devoted to the heat insulation devices 12; mechanical deformations are limited and a fine structure can be used. But this gives a reduced heat insulation and consequently limited detection sensitivity.

In the realization illustrated in figure 7, four physical links are introduced between the detector and the processing circuit, the said links being made up of heat insulation devices 12 accompanying the mechanical support and electrical interconnection devices 11. This realization gives sound mechanical stability of both the structure and the detectors in thin layers. But this has the following disadvantages:

- a reduced active zone 10 due to the number and bulk of the insulation devices 12 and the mechanical support and electrical interconnection devices 11; the fill factor of this type of detector is therefore low;
- a lower heat insulation as heat leakage can spread through eight branches instead of two, hence a sensitivity loss factor of 4.

The aim of the invention is to offer a heat detecting device of electromagnetic radiations comprising microbridge heat detectors using the thinnest and flattest suspended active layers possible.

Account of the invention

The present invention concerns an electromagnetic radiation (EMR) heat detecting device consisting of at least two microbridge detectors with mechanical support devices and a signal processing circuit provided by the

detectors characterized in that the suspended layers of the microbridges of two neighbouring detectors are linked together by additional mechanical connections, separate from the mechanical support devices.

Conveniently each mechanical connection is an extension of at least one of the suspended layers of the microbridges.

Conveniently each mechanical connection is made in low thermal conductivity material.

Conveniently the mechanical connection(s) is(are) aligned with two mechanical support devices, each belonging to one of two neighbouring detectors.

Conveniently the device of the invention can be connected to one or several neighbouring devices by forming a repeat configuration of the said detector following a linear or matrix architecture adapted to the realization of images of electromagnetic wave sources.

The invention concerns more especially the field of infrared detectors based on the principle of a heat detection as opposed to quantic detection, and operating conveniently at ambient temperature.

The invention also concerns a manufacturing process of such a device starting with a processing circuit with metallic contact blocks visible on the surface, passivated by an insulating layer in which openings are made at block level. This process comprises the following stages:

- a reflector on surface of the processing circuit is made by deposit of a metallic coat and definition through photolithography;

- an optical cavity is made by deposit and annealing of a sacrificial layer which is later removed;

- at least two layers are laid constituting the microbridge, i.e.

  - a layer of heat-sensitive material
  - a conducting coat constituting the detector electrodes

- mechanical support and electrical interconnection devices are made

  - by making an etching next to the contact blocks, of the sacrificial layer, of the heat sensitive material and conducting coat
  - by laying and etching at least one metallic coat which provides the electrical and mechanical continuity between the contact blocks and the microbridge electrodes;

- the detector electrodes are defined by etching of the conducting coat;

- the heat-sensitive layer, the conducting coat and the optional layers necessary to make the microbridge are etched simultaneously, using a mask to shield an area located between the detectors.

Conveniently, one can attain the following characteristics. The layer of heat-sensitive material is a layer of amorphous silicon. The conducting coat constituting the detector electrodes is a layer of titanium nitride. The metallic coat which facilitates providing the electrical continuity between the electric blocks and the microbridge electrodes is a layer of aluminium. The metallic coat, constituting the

detector electrodes, is removed in the areas occupied by the mechanical connections. After the definition stage of the detector electrodes through etching of the conducting coat, a final layer can be deposited which can be a layer of silicon dioxide, silicon nitride or amorphous silicon.

In an initial variant of the realization, the connection devices are fined down due to their partial etching. Conveniently the conducting coat and the optional layer can be eliminated at the connections.

In a second realization variant, a connection element made in a material other than those already present in the microbridge, with low heat conductivity is inserted on the microbridges entirely isolated from one another - for example silicon nitride or polymer material.

The invention gives the following advantages as a result:

- Effectiveness of incident wave absorption is optimized, due to a better geometrical conformation of the optical cavity which is a quarter-wave resonant cavity.
- The realization of very thin structures, typically 100 nanometers, or even less, is made possible and no longer in the region of 500 nanometers as in devices of previous technology. Implementation of a microbridge in thin layers also means a reduction in thermal inertia of the detector, and consequently leads to the realization of faster detectors with regard to the modulations of incident flux.

- By favouring the active zone that effectively contributes to the gathering of incident photons, the fill factor is increased. Sensitivity of the detector is therefore increased. Typically the invention results in obtaining a fill factor in the region of 80% which is much higher than the 50% fill factor of the previous technology.

- The mechanical deformations induced by the intrinsic stresses of layers that make up the microbridge are compensated by the mechanical connections. The components made do not therefore require thermal treatment of stress relaxation. The signal processing circuit can thus be conveniently integrated in the detection circuit according to a monolithic structure which is preferable to a hybrid structure in terms of performance and costs.

Brief description of the drawings

Figure 1 shows the schematic diagram of a classic electromagnetic radiation heat detector.

Figures 2 and 3 represent schematically the layout of the various functions necessary for detection.

Figures 4, 5, 6 and 7 show several classic detector structures.

Figure 8 illustrates an initial mode of detection device realization according to the invention.

Figure 9 illustrates a second mode of detection device realization according to the invention.

Figure 10 represents the template of the filter adapted to processing a signal originating from a

central detector with two connection elements in the direction of the neighbouring detectors.

Figures 11A and 11B illustrate two cross-section views of a structure of the invention realized according to a preferred mode in the field of infrared detection.

Figure 12 shows the drawing of a mask which makes the cut-out of a microbridge according to the invention.

Detailed statement of the realization modes

Following the description, similar elements to those of devices from previous technology described above retain the same references.

The present invention concerns an electromagnetic radiation (EMR) heat detecting device consisting of at least two microbridge detectors in which the "suspended" layers of the microbridges are linked between each other by a mechanical connection. These suspended layers are layers of the microbridge which are physically isolated from the substrate and held above the substrate by mechanical support devices.

This device, shown in figure 8, comprises the following elements:

- two mechanical support and electrical interconnection 11 devices per detector;
- two heat insulation 12 devices per detector;
- an active zone sensitive to radiation 10 per detector;
- two mechanical connections 15, 15' which link the central detector 16 mechanically to neighbouring

detectors 17 and 18, and which prevent attenuation of the microbridge zones the furthest away from the mechanical support devices 11.

Each mechanical connection 15, 15' can be an extension of at least one of the microbridge suspended layers. It can be made of material with low thermal conductivity.

The invention device provides reinforced mechanical stability through specific support devices which ensure mechanical continuity between each detector and its nearest neighbours. The realization of a repetitive configuration of the invention detector according to a linear or matrix architecture leads to an assembly of detectors referred to as connected whose mechanical resistance is improved.

Thermal intermodulation IMT which is shown by an electrical intermodulation between neighbouring detectors, is perfectly defined by the respective geometrical dimensions of the heat insulation devices 12 and the mechanical connections 15 and 15', and because of this fact, can be corrected. Foremost one has the following relations:

$$IMT = dT/dTv = Rth / (Rth + 2.Rcx)$$

$$Rth = L_1 / (\lambda_1 .W_1 . E_1)$$

$$Rcx = L_2 / (\lambda_2 .W_2 . E_2)$$

with:

- dT heating of a detector, induced through the mechanical connections, by dTv heating of the neighbouring detector receiving the infrared flux;
- Rth thermal impedance of the heat insulation devices 12;

- Rcx thermal impedance of the mechanical connections 15 and 15';
- λ_1, L_1, W_1, E_1 being respectively the heat conductivity, length, width and thickness of the heat insulation devices 12, and λ_2, L_2, W_2, E_2 represent the same parameters relative to the mechanical connections 15, 15'.

In this particular case where devices 12, 15 and 15' have the same cross-section and an identical heat conductivity, the intermodulation IMT between detectors is expressed:

$$IMT = L_1 / (L_1 + 2 . L_2)$$

The intermodulation between detectors can therefore be limited and adjusted depending on the targeted application, thanks to a competent drawing of devices 12, 15 and 15'. Typically, values in the region of 20% which facilitate making an infrared retina of good quality, can be obtained for connections 15, 15' with double heat insulation arm length 12, as illustrated in figure 9.

One can also totally remove the intermodulation introduced by the connections by carrying out a suitable mathematical processing of the signal originating from the detectors, by inverse filtering of the uncompensated signal contaminated with intermodulation by a filter whose template is defined by the rate of intermodulation. Figure 10 thus represents the pattern of a filter adapted to processing of a signal originating from a central detector 16 with two connection elements to the

neighbouring detectors 17 and 18, and characterized by an intermodulation rate of 10%.

Now we will describe several realization modes for the invention device.

Figures 11A and 11B show two cross-section views of a structure made according to a preferred mode for the invention, representing two neighbouring detectors 16 and 17. The first cross-section (figure 11A) is made outside the connection devices 15 and 15', whilst the second (figure 11B) cuts across the latter.

The manufacturing process of such a device starts with a processing circuit 19 already made, obtained according to known techniques, for example microelectronics on silicon, with metallic contact blocks 20 visible on the surface which facilitate making the electrical connections between the detectors and the processing circuit inputs. These contact blocks 20 are usually passivated with an insulating layer 21 in which openings have been made around the blocks.

A metallic coat 22, in aluminium for example, is conveniently laid and defined by photolithography in order to make an infrared reflector on the surface of the processing circuit 19. The role of this reflector is to optimize absorption of the infrared wave by improving the effectiveness of the quarter-wave resonant cavity constituted by the reflector 22, the microbridge 29 and the space between these two components.

A sacrificial layer 23, made of polyimide for example, is then spread and eventually annealed. This layer on which the microbridge is mounted and which is

removed ultimately, facilitates making the said cavity. The thickness of this layer is usually 2.5 micrometers which facilitates making a sensitive detector in a wavelength range in the region of 10 micrometers.

There are at least 2 layers constituting the microbridge, which are later laid on the sacrificial layer 23:

- a layer 24 of heat-sensitive material which can be amorphous silicon laid following a classic process;

- a conducting coat 25 constituting the detector electrodes which can be titanium nitride laid by reactive sputtering.

The mechanical support and electrical interconnection devices whose realization will be described hereafter, are those of a microbridge in the field of infrared. The practical stages to obtain them are specific, independent of previous stages described and can be replaced by practical stages of other support and interconnection devices.

These mechanical support and electric interconnection devices are thus obtained by making:

- an etching, according to photolithographical processes, of layers 23, 24, and 25 up against the contact blocks 20;

- then, the deposit of one or several metallic coats 26 which provide better electrical and mechanical continuity between the contact blocks and electrodes of the microbridge. This metallic coat is aluminium, for example. This coat 26 is defined and etched according to usual processes, so as to limit the bulk of these interconnection devices to the one surface essential

for sound recovery of contact with the electrode 25 of the detector.

Then the electrodes of the invention device are defined by etching of the metallic coat 25 according to a configuration adapted to the required electrical characteristics for the detector. This coat 25 is conveniently removed from the zones which will be later occupied by the connection components, so as to avoid electric short-circuits between detectors and improve thermal impedance of the connections.

A final layer 28 can also be laid on the microbridge 29 to obtain a symmetrical structure less sensitive to the internal stresses which develop in the layers, by compensating for "bimetal" type phenomena. This layer 28 can either be an electrically active material, possibly of the same type as the heat sensitive material 24, or an electrically neutral material which can be of low heat conductivity as it can increase thermal leakage of the microbridge. Preferably silicon dioxide, silicon nitride or even amorphous silicon is therefore used.

A final photolithographical level facilitates definition of the detector perimeters by simultaneous etching of layers 24, 25 and 28 which results in;

- isolating the detectors from one another;
- defining the heat insulation devices 12 cut in the microbridge 29 itself, in order to make a component of reduced cross-section, of considerable length and sound mechanical resistance between the mechanical support and electrical interconnection device on the one hand, and the detector on the other.

Connections between detectors can also be made during this last stage. By using a suitable sketching mask, the etching of layers 24, 25, 28 shields a specific area of limited extent and located between the detectors, the material shielded constituting the connection devices. The shielded zone is small in cross-section, typically between 0.5 and 3 micrometers wide for a thickness equal to that of the microbridge. The geometrical ratio of the connection to the total perimeter of the detector is therefore very limited which facilitates making detectors of low thermal intermodulation.

Now several variations of the invention device will be considered successively, with the aim of limiting thermal intermodulation between detectors, and at the same time providing satisfactory mechanical resistance.

An initial variant of the invention consists in fining down the connection devices due to a partial etching of the latter. One can either etch one of the layers of the connection elements entirely, or appreciably fine down one of its components by controlling etching time. As an example, the metallic coat 25 and the optional layer 28 can be removed at the connections without in fact limiting mechanical resistance of the whole in any way. This process of local etching calls upon the use of a specific mask and usual photolithography techniques.

A second variant consists in adding a connection element made in a material if necessary different from those already present in the microbridge and chosen for

its favourable thermal characteristics on microbridges which are entirely isolated from one another, for example silicon nitride or polymer materials with low thermal conductivity. Polymers of the PVDF type are especially favourable as they have a lower thermal conductivity to that of silicon dioxide. The usual depositing techniques, in particular PECVD, LPCVD deposits, cathode sputtering, spreading of solution containing a liquid precursor, etc. can be used.

The invention can also be applied to connection devices of geometrical shapes other than rectangular. A design that maximizes the length is advantageous as it limits intermodulation between detectors. As an example, figure 12 shows the design of a mask which makes the cut-out of the microbridge according to the notion of the invention and which maximizes the length of connections.

CLAIMS

1. Electromagnetic radiation heat detecting device consisting of at least two microbridge detectors with mechanical support devices, with a signal processing circuit provided by the detectors characterized in that microbridge suspended layers of two neighbouring detectors (16, 17, 18) are linked together by additional mechanical connections (15, 15'), separate from the mechanical support devices.

2. Device according to claim 1, in which each mechanical connection (15, 15') is an extension of at least one of the suspended microbridge layers.

3. Device according to claim 1, in which each mechanical connection (15, 15') comprises a material with low thermal conductivity.

4. Device according to claim 1, in which the mechanical connection(s) (15,15') is (are) in line with two mechanical support devices (11), each belonging to one of two neighbouring detectors.

5. Device according to any one of the preceding claims in which the said device forms a repetitive detector configuration according to a linear or matrix architecture.

6. Manufacturing process of a device according to any one of the preceding claims, characterized in that by starting from a processing circuit (19) with metallic contact blocks (20) visible on the surface, it comprises the following stages:

- a reflector (22) is made on surface of the processing circuit through deposit of a metallic coat with definition through photolithography;

- an optical cavity is made through deposit of a sacrificial layer (23) which is later removed;

- at least two layers constituting the microbridge are laid, in other words

  - a layer of heat-sensitive material (24),
  - a conducting coat (25) constituting the detector electrodes;

- the mechanical support and electrical interconnection devices are made

  - against the contact blocks, by carrying out an etching of the sacrificial layer (23), the layer of heat sensitive material (24) and the conducting coat (25),
  - by depositing and etching at least one metallic coat (26) which provides the electrical and mechanical continuity between the contact blocks (20) and the microbridge electrodes (25);

- the detector electrodes are defined by etching the conducting coat (25);

- the layer of heat-sensitive material (24), the conducting coat (25) and optional layers (28) are etched simultaneously using a mask to shield a zone located between the detectors;

7. Process according to claim 6, in which the layer of heat-sensitive material (24) is a layer of amorphous silicon.

8. Process according to claim 6, in which the conducting coat (25) constituting the detector electrodes is a layer of titanium nitride.

9. Process according to claim 6 in which a layer of aluminium (26) is deposited which will provide electrical continuity between the electric blocks (20) and the microbridge electrodes (25).

10. Process according to claim 6, in which the metallic coat (25) constituting the detector electrodes, is removed in the zones occupied by the mechanical connections (15, 15').

11. Process according to claim 6 in which, after the definition stage of the detector electrodes by etching of the conducting coat (25), a final layer is deposited (28).

12. Process according to claim 11 in which this last layer (28) is a layer of silicon dioxide, silicon nitride or amorphous silicon.

13. Process according to claim 6 in which the mechanical connections (15, 15') are fined down due to partial etching of the connections.

14. Process according to claim 13 in which the conducting coat (25) and the last layer (28) are removed at the connections.

15. Process according to claim 6 in which a connection element made in a material with low thermal conductivity is added on the microbridges entirely isolated from one another.

16. Process according to claim 15 in which the material with low thermal conductivity is silicon nitride or polymer material.

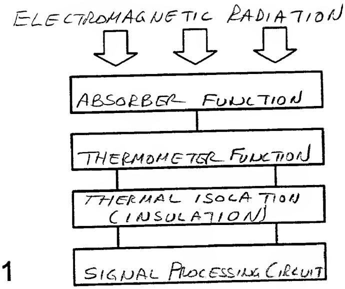

Fig. 1

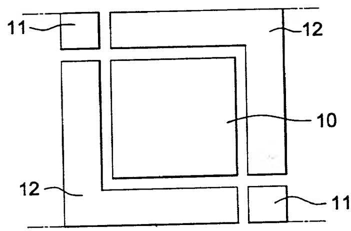

Fig. 2

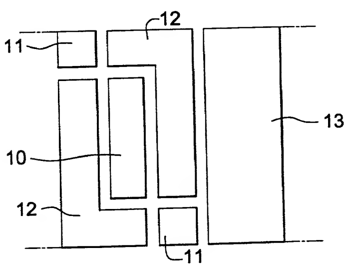

Fig. 3

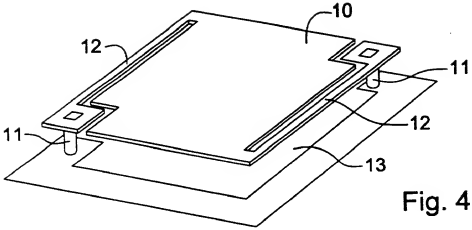

Fig. 4

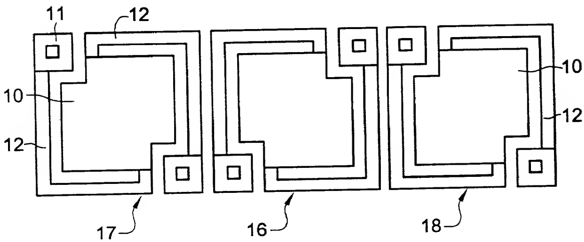

Fig. 5

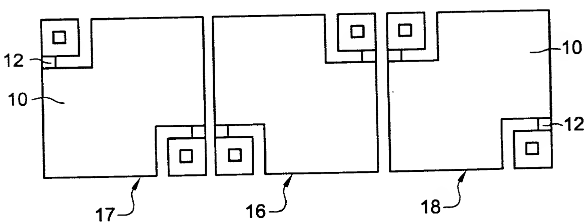

Fig. 6

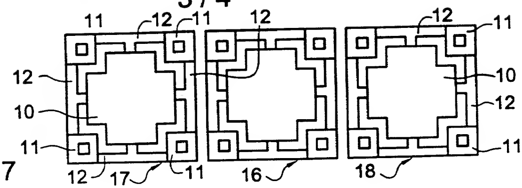

Fig. 7

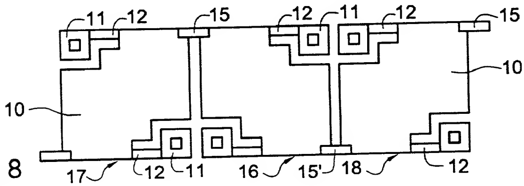

Fig. 8

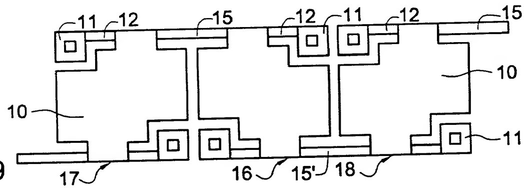

Fig. 9

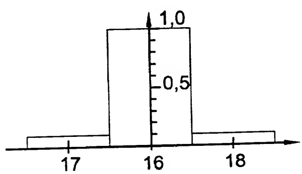

Fig. 10

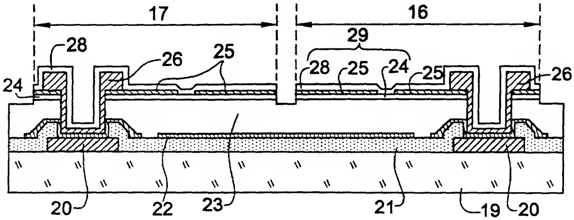

Fig. 11A

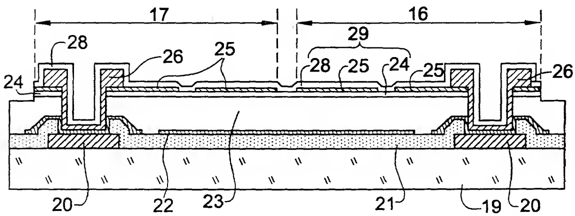

Fig. 11B

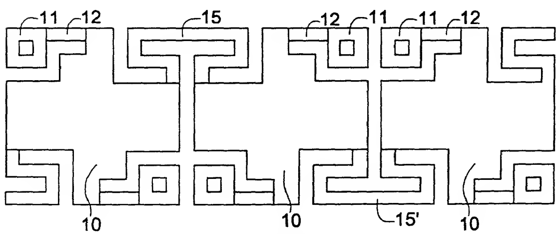

Fig. 12

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JC03 Rec'd PCT/PTC 16 JUL 2001

ELECTROMAGNETIC RADIATION (E.M.R.) HEAT, SENSOR ARRAY AND METHOD FOR MAKING SAME

DESCRIPTION

Technical Field

The present invention concerns an E.M.R. heat detecting device and a manufacturing process for this device.

Status of previous techniques

An E.M.R. detector based on the principle of a heat detecting device such as is represented schematically on Figure 1, is generally made up of different subsystems which carry out the four essential functions necessary for the detection of the radiation, i.e.:

- an absorption function

The absorption function allows converting the energy of the E.M. incident wave, which is characteristic of the temperature and the emissivity of the environment under examination in a heating phase of the detection structure. The parameters which characterize this function are:

- On the one hand the relative absorption (Ar) which defines the ratio of the incident radiation luminance to the luminance actually absorbed by the absorbing structure. A quarter-wave resonant optical cavity facilitates obtaining a relative absorption near to the ideal value of 100%.
- On the other hand the fill factor (Fr) which is the ratio between the useful surface actually involved in heating of the detector with the total surface of the latter. In this way one obtains fill factors in the order of 50%.

Optimization of the absorption function consists therefore essentially in maximizing these Fr and Ar parameters.

- a thermometer function

The thermometer is an element where one of the physical characteristics is sensitive to temperature. This can be the electrical resistivity

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of the material in the case of resistive bolometers, the conductivity of semiconductor devices, residual polarization in the case of a pyroelectric detector, the dielectric constant in the case of a ferroelectric detector, etc. The essential quality factor which characterizes the thermometer function is the relative variation of the physical value observed with the temperature. For a resistive bolometer of R resistance this quality factor is expressed by dR/R.dT, i.e. TCR. Optimization of the thermometer consists in maximizing this parameter.

- a heat insulation function

The thermometer is heat insulated from its environment, for example by placing the thermometer on a suspended diaphragm above a substrate, according to an architecture referred to as "microbridge" which is heat insulated on the one hand by integrating the detector in an environment under reduced gas pressure, and on the other hand by interlacing a specific heat insulation device between the microbridge supporting the thermometer and the down-circuit signal processing circuit. The characteristic thermal parameters are, on the one hand the thermal impedance Rth which should be maximized so as to improve the sensitivity of the detector, and on the other hand the heat capacity Cth which translates the thermal inertia of the thermometer so as to reduce detector response time to an incident flux variation. Response time which is proportional to the result of Rth x Cth, is typically between several milliseconds and several dozen milliseconds. So as to make a detector both sensitive and at the same time rapid, one should attempt to maximize the effectiveness of the heat insulation and reduce the volume of the thermometer to the minimum. This optimization implies making structures in thin layers.

- the signal processing function:

The signal processing function consists in translating the electric signal issued by the thermometer into a video signal which is usable by camera. This function is realized:

- either by hybridization of the detection circuit on the processing circuit; this initial solution which necessitates treating each

component individually, is incompatible with a process where the technological operations of manufacturing are realized simultaneously on a large number of components assembled flat on a substrate. This initial solution therefore poses the problem of high manufacturing cost.

- or by mounting the detector on a microbridge suspended above a pre-existing processing circuit. The component made is then called "monolithic". This second solution which enables one to circumvent the problem of manufacturing cost, imposes severe restrictions on the technological processes which make the detection structure - particularly the heat budget must be limited so as to avoid downgrading the electrical performance of the processing circuit.

Besides these different functions, moreover one must:

- on the one hand maintain the same mechanical balance between the detector and the processing circuit,
- and on the other hand provide the transmission of the electric signal originating from the thermometer to the processing circuit.

The figures 2 and 3 represent schematically the layout of the different functions necessary for detection. Figure 2 refers to an architecture where the detector is mounted above the processing circuit, whereas figure 3 represents a configuration where these two elements are side by side.

On these two figures, the following are shown:

- a zone 10 which constitutes the thermometer and corresponds to the active zone of the detector which actually collects the incident photons
- zones 11 which constitute the mechanical support and electrical interconnection devices between the detector and the processing circuit
- zones 12 which constitute the detector heat insulation devices
- and a zone 13 which represents the signal processing circuit.

On figure 2, the zone 13 is not represented, as this is located under the detector.

The devices 11, 12 and 13 are not involved in detection - to maximize the fill factor one should therefore limit the surface necessary for their realization, by:

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- limiting their number to the bare minimum, for example, to two;

- limiting their size, by reducing the length of the heat insulation devices, and therefore their cross-section and thickness so as to retain sufficient heat insulation.

- choosing the architecture where the detector is mounted on the processing circuit according to a monolithic architecture.

The European EP-0 354 369 patent request describes in this manner an infrared monolithic uncooled detector network of bolometers made on a silicon substrate. The bolometers comprise a silicon dioxide cell of TiN (titanium nitride), a-Si:H (hydrogenated amorphous silicon), TiN and silicon dioxide. The titanium nitride forms the infrared absorber and the resistor contacts, and the amorphous silicon, the resistance with a high temperature resistivity factor. The resistor is suspended above the silicon substrate by metal interconnections and the accompanying processing circuit takes shape in the silicon substrate under the resistor.

To minimize the mechanical deformations of fine structures set up, an initial solution consists in compensating the stresses that develop in a thin layer by the arrangement of an additional layer in contact with this layer.

The second solution consists in reducing the amplitude of the intrinsic stress of materials used by calling upon heat treatment at high temperatures in order to relieve the stresses. But this solution leads to thermally restricting the electronic processing circuit disposed in layers under the detector and to downgrading functionality of the said circuit.

For the time being we shall consider several examples for realization according to previous technology.

Figure 4 represents a perspective view of a unit detector characterized by heat insulation devices 12 of intermediate length.

Structures made, illustrated in figures 5, 6 and 7, show more often than not an outline sketch of three neighbouring detectors 16, 17 and 18 as part of a generally more complex structure, multi-element linear array strip or forming two sizes of detectors.

In the realization illustrated in figure 5, heat insulation is maximized thanks to very long heat insulation devices 12, accompanying the mechanical support and electrical interconnection devices 11. This realization presents the following disadvantages:

- a reduced active zone 10 due to the bulk of insulation devices, hence a low fill factor;

- a tendency of the part 12 to sag due to its length, which necessitates a thicker diaphragm to ensure the mechanical stiffness.

In the realization illustrated in figure 6, the fill factor is maximized by limiting the surface devoted to the heat insulation devices 12; mechanical deformations are limited and a fine structure can be used. But this gives a reduced heat insulation and consequently limited detection sensitivity.

In the realization illustrated in figure 7, four physical links are introduced between the detector and the processing circuit, the said links being made up of heat insulation devices 12 accompanying the mechanical support and electrical interconnection devices 11. This realization gives sound mechanical stability of both the structure and the detectors in thin layers. But this has the following disadvantages:

- a reduced active zone 10 due to the number and bulk of the insulation devices 12 and the mechanical support and electrical interconnection devices 11; the fill factor of this type of detector is therefore low;

- a lower heat insulation as heat leakage can spread through eight branches instead of two, hence a sensitivity loss factor of 4.

The aim of the invention is to offer a heat detecting device of electromagnetic radiations comprising microbridge heat detectors using the thinnest and flattest suspended active layers possible.

<u>Account of the invention</u>

The present invention concerns an electromagnetic radiation (EMR) heat detecting device consisting of at least two microbridge detectors with mechanical support devices and a signal processing circuit provided by the detectors characterized in that the suspended layers of the microbridges of

two neighbouring detectors are linked together by additional mechanical connections, separate from the mechanical support devices.

Conveniently each mechanical connection is an extension of at least one of the suspended layers of the microbridges.

Conveniently each mechanical connection is made in low thermal conductivity material.

Conveniently the mechanical connection(s) is(are) aligned with two mechanical support devices, each belonging to one of two neighbouring detectors.

Conveniently the device of the invention can be connected to one or several neighbouring devices by forming a repeat configuration of the said detector following a linear or matrix architecture adapted to the realization of images of electromagnetic wave sources.

The invention concerns more especially the field of infrared detectors based on the principle of a heat detection as opposed to quantic detection, and operating conveniently at ambient temperature.

The invention also concerns a manufacturing process of such a device starting with a processing circuit with metallic contact blocks visible on the surface, passivated by an insulating layer in which openings are made at block level. This process comprises the following stages:

- a reflector on surface of the processing circuit is made by deposit of a metallic coat and definition through photolithography;

- an optical cavity is made by deposit and annealing of a sacrificial layer which is later removed;

- at least two layers are laid constituting the microbridge, i.e.

  - a layer of heat-sensitive material
  - a conducting coat constituting the detector electrodes

- mechanical support and electrical interconnection devices are made

  - by making an etching next to the contact blocks, of the sacrificial layer, of the heat sensitive material and conducting coat

- by laying and etching at least one metallic coat which provides the electrical and mechanical continuity between the contact blocks and the microbridge electrodes;

- the detector electrodes are defined by etching of the conducting coat;

- the heat-sensitive layer, the conducting coat and the optional layers necessary to make the microbridge are etched simultaneously, using a mask to shield an area located between the detectors.

Conveniently, one can attain the following characteristics. The layer of heat-sensitive material is a layer of amorphous silicon. The conducting coat constituting the detector electrodes is a layer of titanium nitride. The metallic coat which facilitates providing the electrical continuity between the electric blocks and the microbridge electrodes is a layer of aluminium. The metallic coat, constituting the detector electrodes, is removed in the areas occupied by the

mechanical connections. After the definition stage of the detector electrodes through etching of the conducting coat, a final layer can be deposited which can be a layer of silicon dioxide, silicon nitride or amorphous silicon.

In an initial variant of the realization, the connection devices are fined down due to their partial etching. Conveniently the conducting coat and the optional layer can be eliminated at the connections.

In a second realization variant, a connection element made in a material other than those already present in the microbridge, with low heat conductivity is inserted on the microbridges entirely isolated from one another - for example silicon nitride or polymer material.

The invention gives the following advantages as a result:

- Effectiveness of incident wave absorption is optimized, due to a better geometrical conformation of the optical cavity which is a quarter-wave resonant cavity.

- The realization of very thin structures, typically 100 nanometers, or even less, is made possible and no longer in the region of 500 nanometers as in devices of previous technology. Implementation of a microbridge in thin layers also means a reduction in thermal inertia of the

detector, and consequently leads to the realization of faster detectors with regard to the modulations of incident flux.

- By favouring the active zone that effectively contributes to the gathering of incident photons, the fill factor is increased. Sensitivity of the detector is therefore increased. Typically the invention results in obtaining a fill factor in the region of 80% which is much higher than the 50% fill factor of the previous technology.

- The mechanical deformations induced by the intrinsic stresses of layers that make up the microbridge are compensated by the mechanical connections. The components made do not therefore require thermal treatment of stress relaxation. The signal processing circuit can thus be conveniently integrated in the detection circuit according to a monolithic structure which is preferable to a hybrid structure in terms of performance and costs.

<u>Brief description of the drawings</u>

Figure 1 shows the schematic diagram of a classic electromagnetic radiation heat detector.

Figures 2 and 3 represent schematically the layout of the various functions necessary for detection.

Figures 4, 5, 6 and 7 show several classic detector structures.

Figure 8 illustrates an initial mode of detection device realization according to the invention.

Figure 9 illustrates a second mode of detection device realization according to the invention.

Figure 10 represents the template of the filter adapted to processing a signal originating from a central detector with two connection elements in the direction of the neighbouring detectors.

Figures 11A and 11B illustrate two cross-section views of a structure of the invention realized according to a preferred mode in the field of infrared detection.

Figure 12 shows the drawing of a mask which makes the cut-out of a microbridge according to the invention.

Detailed statement of the realization modes

Following the description, similar elements to those of devices from previous technology described above retain the same references.

The present invention concerns an electromagnetic radiation (EMR) heat detecting device consisting of at least two microbridge detectors in which the "suspended" layers of the microbridges are linked between each other by a mechanical connection. These suspended layers are layers of the microbridge which are physically isolated from the substrate and held above the substrate by mechanical support devices.

This device, shown in figure 8, comprises the following elements:

- two mechanical support and electrical interconnection 11 devices per detector;
- two heat insulation 12 devices per detector;
- an active zone sensitive to radiation 10 per detector;
- two mechanical connections 15, 15' which link the central detector 16 mechanically to neighbouring detectors 17 and 18, and which prevent attenuation of the microbridge zones the furthest away from the mechanical support devices 11.

Each mechanical connection 15, 15' can be an extension of at least one of the microbridge suspended layers. It can be made of material with low thermal conductivity.

The invention device provides reinforced mechanical stability through specific support devices which ensure mechanical continuity between each detector and its nearest neighbours. The realization of a repetitive configuration of the invention detector according to a linear or matrix architecture leads to an assembly of detectors referred to as connected whose mechanical resistance is improved.

Thermal intermodulation IMT which is shown by an electrical intermodulation between neighbouring detectors, is perfectly defined by the

respective geometrical dimensions of the heat insulation devices 12 and the mechanical connections 15 and 15', and because of this fact, can be corrected. Foremost one has the following relations:

$$IMT = dT/dTv = Rth / (Rth + 2.Rcx)$$

$$Rth = L_1 / (\lambda_1 .W_1. E_1)$$

$$Rcx = L_2 / (\lambda_2 .W_2. E_2)$$

with:

- dT heating of a detector, induced through the mechanical connections, by dTv heating of the neighbouring detector receiving the infrared flux;
- Rth thermal impedance of the heat insulation devices 12;
- Rcx thermal impedance of the mechanical connections 15 and 15';
- λ_1, L_1,W_1, E_1 being respectively the heat conductivity, length, width and thickness of the heat insulation devices 12, and λ_2, L_2,W_2, E_2 represent the same parameters relative to the mechanical connections 15, 15'.

In this particular case where devices 12, 15 and 15' have the same cross-section and an identical heat conductivity, the intermodulation IMT between detectors is expressed:

$$IMT = L_1 / (L_1 + 2. L_2)$$

The intermodulation between detectors can therefore be limited and adjusted depending on the targeted application, thanks to a competent drawing of devices 12, 15 and 15'. Typically, values in the region of 20% which facilitate making an infrared retina of good quality, can be obtained for connections 15, 15' with double heat insulation arm length 12, as illustrated in figure 9.

One can also totally remove the intermodulation introduced by the connections by carrying out a suitable mathematical processing of the signal originating from the detectors, by inverse filtering of the uncompensated signal contaminated with intermodulation by a filter whose template is defined

by the rate of intermodulation. Figure 10 thus represents the pattern of a filter adapted to processing of a signal originating from a central detector 16 with two connection elements to the neighbouring detectors 17 and 18, and characterized by an intermodulation rate of 10%.

Now we will describe several realization modes for the invention device.

Figures 11A and 11B show two cross-section views of a structure made according to a preferred mode for the invention, representing two neighbouring detectors 16 and 17. The first cross-section (figure 11A) is made outside the connection devices 15 and 15', whilst the second (figure 11B) cuts across the latter.

The manufacturing process of such a device starts with a processing circuit 19 already made, obtained according to known techniques, for example microelectronics on silicon, with metallic contact blocks 20 visible on the surface which facilitate making the electrical connections between the detectors and the processing circuit inputs. These contact blocks 20 are usually passivated with an insulating layer 21 in which openings have been made around the blocks.

A metallic coat 22, in aluminium for example, is conveniently laid and defined by photolithography in order to make an infrared reflector on the surface of the processing circuit 19. The role of this reflector is to optimize absorption of the infrared wave by improving the effectiveness of the quarter-wave resonant cavity constituted by the reflector 22, the microbridge 29 and the space between these two components.

A sacrificial layer 23, made of polyimide for example, is then spread and eventually annealed. This layer on which the microbridge is mounted and which is removed ultimately, facilitates making the said cavity. The thickness of this layer is usually 2.5 micrometers which facilitates making a sensitive detector in a wavelength range in the region of 10 micrometers.

There are at least 2 layers constituting the microbridge, which are later laid on the sacrificial layer 23:

- a layer 24 of heat-sensitive material which can be amorphous silicon laid following a classic process;

- a conducting coat 25 constituting the detector electrodes which can be titanium nitride laid by reactive sputtering.

The mechanical support and electrical interconnection devices whose realization will be described hereafter, are those of a microbridge in the field of infrared. The practical stages to obtain them are specific, independent of previous stages described and can be replaced by practical stages of other support and interconnection devices.

These mechanical support and electric interconnection devices are thus obtained by making:

- an etching, according to photolithographical processes, of layers 23, 24, and 25 up against the contact blocks 20;

- then, the deposit of one or several metallic coats 26 which provide better electrical and mechanical continuity between the contact blocks and electrodes of the microbridge. This metallic coat is aluminium, for example. This coat 26 is defined and etched according to usual processes, so as to limit the bulk of these interconnection devices to the one surface essential for sound recovery of contact with the electrode 25 of the detector.

Then the electrodes of the invention device are defined by etching of the metallic coat 25 according to a configuration adapted to the required electrical characteristics for the detector. This coat 25 is conveniently removed from the zones which will be later occupied by the connection components, so as to avoid electric short-circuits between detectors and improve thermal impedance of the connections.

A final layer 28 can also be laid on the microbridge 29 to obtain a symmetrical structure less sensitive to the internal stresses which develop in the layers, by compensating for "bimetal" type phenomena. This layer 28 can either be an electrically active material, possibly of the same type as the heat sensitive material 24, or an electrically neutral material which can be of low heat conductivity as it can increase thermal leakage of the microbridge.

Preferably silicon dioxide, silicon nitride or even amorphous silicon is therefore used.

A final photolithographical level facilitates definition of the detector perimeters by simultaneous etching of layers 24, 25 and 28 which results in;

- isolating the detectors from one another;

- defining the heat insulation devices 12 cut in the microbridge 29 itself, in order to make a component of reduced cross-section, of considerable length and sound mechanical resistance between the mechanical support and electrical interconnection device on the one hand, and the detector on the other.

Connections between detectors can also be made during this last stage. By using a suitable sketching mask, the etching of layers 24, 25, 28 shields a specific area of limited extent and located between the detectors, the material shielded constituting the connection devices. The shielded zone is small in cross-section, typically between 0.5 and 3 micrometers wide for a thickness equal to that of the microbridge. The geometrical ratio of the connection to the total perimeter of the detector is therefore very limited which facilitates making detectors of low thermal intermodulation.

Now several variations of the invention device will be considered successively, with the aim of limiting thermal intermodulation between detectors, and at the same time providing satisfactory mechanical resistance.

An initial variant of the invention consists in fining down the connection devices due to a partial etching of the latter. One can either etch one of the layers of the connection elements entirely, or appreciably fine down one of its components by controlling etching time. As an example, the metallic coat 25 and the optional layer 28 can be removed at the connections without in fact limiting mechanical resistance of the whole in any way. This process of local etching calls upon the use of a specific mask and usual photolithography techniques.

A second variant consists in adding a connection element made in a material if necessary different from those already present in the microbridge and chosen for its favourable thermal characteristics on microbridges which

are entirely isolated from one another, for example silicon nitride or polymer materials with low thermal conductivity. Polymers of the PVDF type are especially favourable as they have a lower thermal conductivity to that of silicon dioxide. The usual depositing techniques, in particular PECVD, LPCVD deposits, cathode sputtering, spreading of solution containing a liquid precursor, etc. can be used.

The invention can also be applied to connection devices of geometrical shapes other than rectangular. A design that maximizes the length is advantageous as it limits intermodulation between detectors. As an example, figure 12 shows the design of a mask which makes the cut-out of the microbridge according to the notion of the invention and which maximizes the length of connections.

CLAIMS

1. Electromagnetic radiation heat detecting device consisting of at least two microbridge detectors with mechanical support devices, with a signal processing circuit provided by the detectors characterized in that microbridge suspended layers of two neighbouring detectors (16, 17, 18) are linked together by additional mechanical connections (15, 15'), separate from the mechanical support devices.

2. Device according to claim 1, in which each mechanical connection (15, 15') is an extension of at least one of the suspended microbridge layers.

3. Device according to claim 1, in which each mechanical connection (15, 15') comprises a material with low thermal conductivity.

4. Device according to claim 1, in which the mechanical connection(s) (15,15') is (are) in line with two mechanical support devices (11), each belonging to one of two neighbouring detectors.

5. Device according to any one of the preceding claims in which the said device forms a repetitive detector configuration according to a linear or matrix architecture.

6. Manufacturing process of a device according to any one of the preceding claims, characterized in that by starting from a processing circuit (19) with metallic contact blocks (20) visible on the surface, it comprises the following stages:

- a reflector (22) is made on surface of the processing circuit through deposit of a metallic coat with definition through photolithography;

- an optical cavity is made through deposit of a sacrificial layer (23) which is later removed;

- at least two layers constituting the microbridge are laid, in other words
    - a layer of heat-sensitive material (24),
    - a conducting coat (25) constituting the detector electrodes;

- the mechanical support and electrical interconnection devices are made

- against the contact blocks, by carrying out an etching of the sacrificial layer (23), the layer of heat sensitive material (24) and the conducting coat (25),
- by depositing and etching at least one metallic coat (26) which provides the electrical and mechanical continuity between the contact blocks (20) and the microbridge electrodes (25);

- the detector electrodes are defined by etching the conducting coat (25);

- the layer of heat-sensitive material (24), the conducting coat (25) and optional layers (28) are etched simultaneously using a mask to shield a zone located between the detectors;

7. Process according to claim 6, in which the layer of heat-sensitive material (24) is a layer of amorphous silicon.

8. Process according to claim 6, in which the conducting coat (25) constituting the detector electrodes is a layer of titanium nitride.

9. Process according to claim 6 in which a layer of aluminium (26) is deposited which will provide electrical continuity between the electric blocks (20) and the microbridge electrodes (25).

10. Process according to claim 6, in which the metallic coat (25) constituting the detector electrodes, is removed in the zones occupied by the mechanical connections (15, 15').

11. Process according to claim 6 in which, after the definition stage of the detector electrodes by etching of the conducting coat (25), a final layer is deposited (28).

12. Process according to claim 11 in which this last layer (28) is a layer of silicon dioxide, silicon nitride or amorphous silicon.

13. Process according to claim 6 in which the mechanical connections (15, 15’) are fined down due to partial etching of the connections.

14. Process according to claim 13 in which the conducting coat (25) and the last layer (28) are removed at the connections.

15. Process according to claim 6 in which a connection element made in a material with low thermal conductivity is added on the microbridges entirely isolated from one another.

16. Process according to claim 15 in which the material with low thermal conductivity is silicon nitride or polymer material.

ABSTRACT OF THE DISCLOSURE

The present invention concerns an electromagnetic radiation (EMR) heat detecting device consisting of at least two microbridge detectors with mechanical support devices with a signal processing circuit provided by the detectors in which microbridge suspended layers of two neighbouring detectors (16, 17, 18) are linked together by additional mechanical connections (15, 15') separate from the mechanical support devices.

The present invention equally concerns the manufacturing process of such a device.

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ABSTRACT OF THE DISCLOSURE

The present invention concerns an electromagnetic radiation (EMR) heat detecting device consisting of at least two microbridge detectors with mechanical support devices with a signal processing circuit provided by the detectors in which microbridge suspended layers of two neighbouring detectors (16, 17, 18) are linked together by additional mechanical connections (15, 15') separate from the mechanical support devices.

The present invention equally concerns the manufacturing process of such a device.

<u>Figure 8</u>

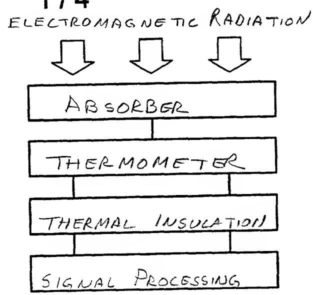

Fig. 1

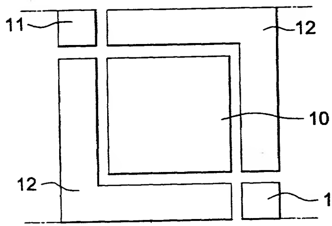

Fig. 2

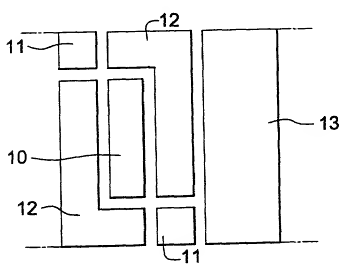

Fig. 3

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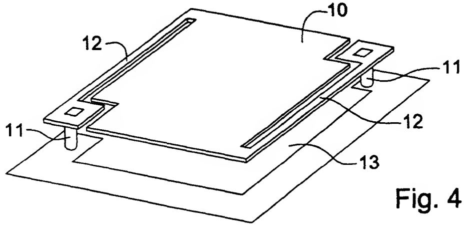

Fig. 4

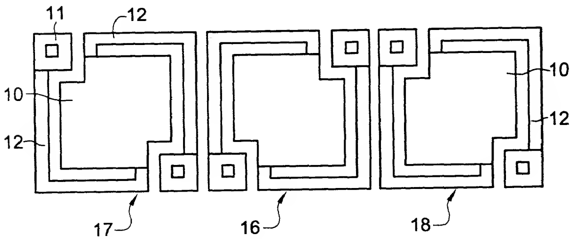

Fig. 5

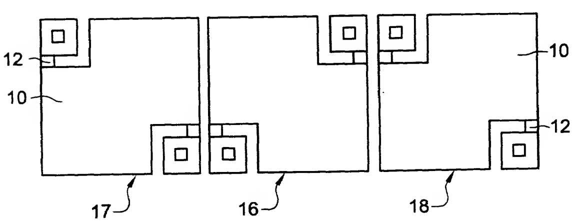

Fig. 6

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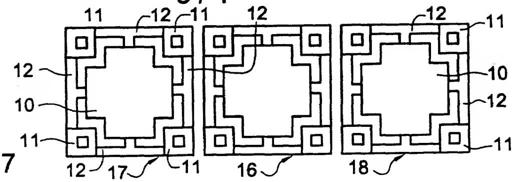

Fig. 7

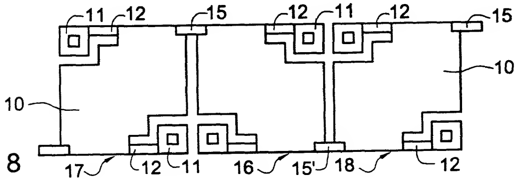

Fig. 8

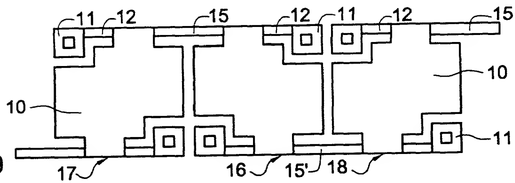

Fig. 9

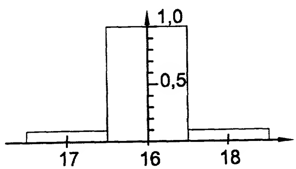

Fig. 10

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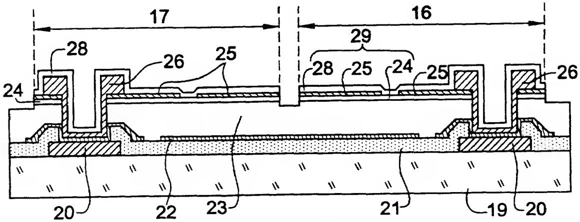

Fig. 11A

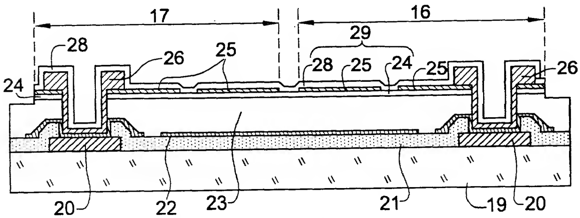

Fig. 11B

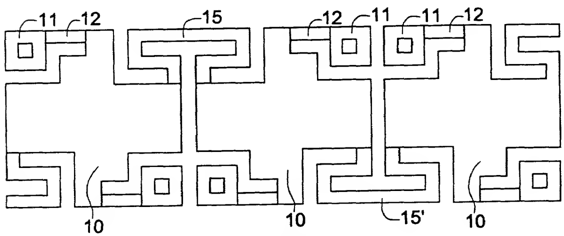

Fig. 12

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Declaration, Power Of Attorney and Petition

OIPE JC106 DEC 17 2001 PATENT & TRADEMARK OFFICE

WE (I) the undersigned inventor(s), hereby declare(s) that :

My residence, post office address and citizenship are as stated below next to my name,

We (I) believe that we are (I am) the original, first, and joint (sole) inventor(s) of the subject matter which is claimed and for which a patent is sought on the invention entitled

E.M.R HEAT DETECTING DEVICE AND ITS MANUFACTURING PROCESS

the specification of which

☐ is attached hereto.

☐ was filed on

as Application Serial No.

and amended on

☒ was filed as PCT international application

Number PCT/FR00/00120

on January 20, 2000

and was amended under PCT Article 19

on

We (I) hereby state that we (I) have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

We (I) acknowledge the duty to disclose information known to be material to the patentability of this application as defined in Section 1.56 of Title 37 Code of Federal Regulations.

We (I) hereby claim foreign priority benefits under 35 U.S.C. § 119 (a)-(d) or § 365 (b) of any foreign application(s) for patent or inventor's certificate, or § 365 (a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed. Prior Foreign Application (s)

Application No.	Country	Day/month/Year	Priority Claimed
99 00632	FRANCE	21 JANUARY 1999	☒ YES ☐ NO
			☐ YES ☐ NO
			☐ YES ☐ NO
			☐ YES ☐ NO

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3-0

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NAME OF FOURTH INVENTOR

Signature of Inventor

Date

Residence :

Citizen of :

Post Office Address : The same as residence

NAME OF FIFTH INVENTOR

Signature of Inventor

Date

Residence :

Citizen of :

Post Office Address : The same as residence

We (I) hereby claim the benefit under Title 35, United States Code, § 119 (e) of any United States provisional application(s) listed below.

(Application Number)	(Filing Date)
(Application Number)	(Filing Date)

We (I) hereby claim the benefit under 35 U.S.C. §120 of any United States application(s), or § 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56 which became available between the filing date of prior application and the national or PCT International filing date of this application.

Application Serial No.	Filing Date	Status (pending, patented, abandoned)

And we (I) hereby appoint : BLAIR Charles H., BRENNAN Michael P., BROCK Christopher M., BUDDE Anna M., BURRIS Kelly K., CANTOR Bernard J., CARLSON Richard L., DESCHERE Linda M., DONLEY Garrett C., ELCHUK Mark D., ERJAVAC Stanley M. , EUSEBI Christopher A., FALCOFF Monte L., FOSS Stephen J., FRENTRUP Mark A., FULLER Roland A., GIBBS Barbara S., GAMBRELL Myriah M., HALLIN Thomas H., HARRIS Gordon H., JORDAN B. Delano, KELLER Paul A., KICZEK Casimir R., LAFATA Joseph L., LALONE Douglas P., MACINTYRE Timothy D., MALINZAK Michael, MASSEY Ryan W., MCCLAUGHRY David A., MILLER H. Keith, MILLER John A., MOUSTAKAS George D., NOLAN Robert S., O'DELL Elizabeth D., OLSON Stephen T., PAPP Joseph R., RETTIG Phillip E., SCHIVLEY G. Gregory, SCHMIDT Michael J., SCHOOF George T., SIMINSKI Robert M., SMIRMAN Preston H., SNYDER Jeffrey L., SOSENKO Eric J., SOTIRIOU Evan A., STEPHENSON James E., STEVENSON Joseph L., STOBBS Gregory A., TAYLOR W.R. Duke, TELSCHER Rudolph A., UTYKANSKI David P., WADE Bryant E., WALKER Donald G., WALLACE Robert J., WALSH Joseph E., WANGEROW Ronald W., WARNER Richard W., WHEELOCK Bryan K., WIGGINS Michael D., ZALOBSKI Michael D., our (my) attorneys, with full powers of substitution and revocation, to prosecute this application and to transact all business in the Patent Office connected therewith; and we (I) hereby request that all correspondence regarding this application be sent to the firm of HARNESS, DICKEY & PIERCE, P.L.C.. whose Address is . P.O. Box 828, Bloomfield Hills, Michigan 48303.

We (I) declare that all statements made herein of our (my) own knowledge are true and that all statements made on information and belief are believed to be true ; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such wilful false statements may jeopardise the validity of the application or any patent issuing thereon.

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